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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report presents an alternative to the 90-90 rule for assessing the impact of spare parts support during initial deployment. The method is felt to be an improvement to 90-90 because it considers the relative failure rates of the spares, and because it distinguishes reparable components from repair parts. An effort was made to keep the model simple.			

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# A SIMPLE MODEL FOR ASSESSING THE IMPACT OF SPARE PARTS DURING INITIAL DEPLOYMENT OF NEW WEAPONS SYSTEMS

## Background

When new weapons systems are ready to be fielded, parts support may not be sufficient to allow the system to function at an acceptable level. Recently, DARCOM has been using a simple, but arbitrary, statistical criterion to determine when parts support is sufficient. The criterion is called the 90-90 rule and requires that at least 90% of the stockage lines and 90% of the stockage quantity be available before the system is fielded.

New policies in the provisioning area are now being evaluated and, as a result, DARCOM requested the Inventory Research Office (IRO) with assistance from the Army Materiel Systems Analysis Activity to determine the propriety of the 90-90 rule. It was hoped to determine the effect of using 90-90, as well as other forms, 85-85 for example, on the operational readiness of the system.

## Complicating Factors

Even in the cleanest of weapon system operating environments, the state of the art in modelling is just reaching the point where long term or steady state operational readiness can be estimated as a function of parts stockage. Yet in this case, we must deal with, probably, the most turbulent period in the life of the weapon system.

The form of the rule itself presents other problems. It is often pointed out that 90-90, or any similar combination except 100-100, does not guarantee that the "right" items are on hand. In statistical jargon, the 90-90 rule is considered an indicator, but it does not guarantee a prescribed operational availability. The important factors that affect operational availability are

- (1) the maintenance factor of the part,
  - (2) the number of applications of the part on the equipment,
  - (3) redundancy of the part on the system,
  - (4) location of parts in supply system,
- and (5) due-in status of parts on-order.

Another factor which needs to be considered is the deployment plan for the system since this indicates the ultimate use of the parts due-in.

It is probably possible to build a computer simulator to model the transient state and account for at least the above factors, but such an approach would be time consuming, costly, and possibly intractable.

### Model

Because of the above problems, we limited our efforts to developing a better indicator to replace the 90-90 type of rule. We will first describe the model and then discuss its virtues.

### Definitions

MTBF = mean time between system failures

MTTR = mean time to restore system not including parts delays

$A_{LRU}$  = accommodation provided by LRU's for which there is stock.

An LRU in this case is any reparable component whose failure will down the system.

$A_{RP}$  = accommodation provided by repair parts for which there is stock

TAT = average time to repair LRU's

NMOS = time horizon

$[X]$  = largest integer  $\leq X$

### Assumptions

1. System up times and down times are deterministic.
2. If a component is in stock at the beginning of the time horizon, there is never a shortage of that component during the time horizon.
3. No additional components arrive during the time horizon.

Let  $q_r$  = probability system cannot be restored if it fails.

$$= 1 - \text{Pr}$$

We estimate  $q_r = (1 - A_{LRU})(1 - A_{RP})$  since if the LRU and the repair part are not available, the system cannot be repaired. The accommodation rates,  $A_{LRU}$  and  $A_{RP}$ , are used to estimate the probability that the LRU and repair part, respectively, are available.

If all failures can be repaired, then the maximum number of cycles which can begin in NMOS is

$$C_{MAX} = 1 + \left\lceil \frac{NMOS}{MTBC} \right\rceil \quad \text{where}$$

$$MTBC = MTBF + MTTR + (1 - A_{LRU})(A_{RP})(TAT)$$

= the average cycle length, i.e., the average time from when a system begins an up period until it begins its next up period.

Now without regard for the time horizon, we let  $P(k)$  = probability the number of cycles is  $\geq k$ . We set  $P(k) = (Pr)^{k-1}$  which assumes that the probability of being able to restore the system on the  $n^{th}$  cycle is independent of what happens on all other cycles.

If  $C_{MAX} = 1$ , then

$$\begin{aligned} UPTIME &= \text{time system is operating during NMOS} \\ &= \text{minimum (MTBF, NMOS)} \end{aligned}$$

If  $C_{MAX} \geq 2$ , then

$$UPTIME = \sum_{k=1}^{C_{MAX}-1} (MTBF)(P(k)) + (REM)(P(C_{MAX}))$$

where

$$REM = \text{Min} ((NMOS - (C_{MAX}-1)(MTBC)), MTBF)$$

= the uptime in the  $C_{MAX}^{th}$  cycle which occurs within NMOS

As an indicator of the operational readiness during NMOS we use

$$ORIndicator = UPTIME/NMOS$$

The following table shows an example of the model for several values of NMOS,  $A_{RP}$ , and  $A_{LRU}$ . MTTR was set to .1 months, MTBF to .5618 months, and TAT to .666 months.

NMOS	$A_{LRU}$	$A_{RP}$	ORIndicator
2	.70	.70	.701
2	.70	.80	.703
2	.70	.95	.702
2	.80	.70	.761
2	.80	.80	.764
2	.80	.95	.766
2	.95	.70	.830
2	.95	.80	.834
2	.95	.95	.841
6	.70	.70	.536
6	.70	.80	.575
6	.70	.95	.632
6	.80	.70	.609
6	.80	.80	.652
6	.80	.95	.711
6	.95	.70	.788
6	.95	.80	.799
6	.95	.95	.816

This approach improves upon the 90-90 type rule in several ways. For one, it uses accommodation which simultaneously accounts for the number of parts in stock and their expected demands. Accommodation will be high only if the most important items are in stock. All of the necessary information to compute accommodation is available from the PMDR or as a by-product from ARCSIP.

Another improvement is that it distinguishes reparable components from repair parts. If a component fails, the consequences are much more severe if the repair parts are not available to fix the component. On the other hand, the component can be repaired and replaced on the system in a reasonable time if the repair parts are available. A weakness of the approach,



however, is that it does not recognize that the serviceable stock of components may be depleted if there are no repair parts to fix them.

The model also uses a finite time horizon to deal with the transient nature of the problem. Since the model is meant to be used to assess whether equipment should be fielded given current stock status, and since presumably the stock situation can only improve with time, it is appropriate to use the model with short time horizons where the assumptions are most valid.

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